4.0 Dispersion Modeling

4.1 Executive Summary

The Dispersion Modeling workgroup recommends application of the American Meteorological Society / Environmental Protection Agency Regulatory Model (AERMOD)[3] for estimation of odor, hydrogen sulfide and ammonia impacts from AFOs.   Additionally, the workgroup makes two sub-recommendations:

1. Review of new or enhanced dispersion modeling systems should be conducted on an annual basis in order to take advantage of emerging scientific advances associated with estimation of the dispersion of odor, hydrogen sulfide and ammonia emissions from AFOs.

2. Investigation of proper model configuration and setting selection is necessary to more fully evaluate the suitability of the AERMOD dispersion modeling system for estimating odor, hydrogen sulfide and ammonia concentrations at separated locations.

Development of these recommendations was accomplished through the voluntary participation of interested stakeholders and staff from the DNR.

4.2 Purpose

The charge of the workgroup on dispersion modeling was to identify modeling tools currently available that can be used to assess ambient concentrations of odor, hydrogen sulfide and ammonia from AFOs.

Dispersion models are routinely used to estimate the concentration of pollutants emitted into the atmosphere.   These models use mathematical representations of physical and chemical atmospheric processes in combination with characterization of air pollutant emissions to simulate the transport and diffusion of pollutants from a source of release. Various types of dispersion models have been developed to represent different types of emission release scenarios. The most commonly used types of dispersion model are those based on proven Gaussian dispersion methodology. Employed as the preferred type of model for simulating air pollutant emissions from industrial sources, this class of model has undergone significant scientific scrutiny and peer review for application in assessing pollutants with National Ambient Air Quality Standards. The resulting user base and development community includes federal, state, private and educational entities.

Additional classes of models have been developed to assess a range of requirements for estimating pollutant concentrations. These models include emergency release models used to estimate danger zones from the accidental or intentional release of hazardous substances to models designed to evaluate the transport of pollutants on a global scale.

Independent of the type or class of model employed in a particular study, models allow users to evaluate the results of multiple scenarios on multiple locations in a manner where variables can be controlled. In the case of dispersion modeling for the protection of air quality in the vicinity of an industrial facility, model simulations allow the facility and regulatory agency to evaluate air quality concerns for multiple configurations prior to construction or changes at the facility. In this way, models are capable of helping

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[3] http://www.epa.gov/scram001/7thconf/aermod/aermodug.pdf

to mitigate not only adverse air quality but also unnecessary expenses associated with identifying and rectifying problems after an air pollution source is constructed and operating.

Though models produce estimates based on a simplified representation of real world conditions, they in effect establish "virtual" monitors, or receptors that can be located in the model as specified by the user. In reality, siting of ambient air quality monitors is limited by the need for nearby resources such as electricity and surrounding land use or ownership issues. Additionally, the acquisition, siting and continued operation and maintenance of ambient air quality monitors is resource intensive whereas hundreds or thousands of model receptors can be easily established in a model.

Unlike actual measurements of air pollutant concentrations at ambient air monitoring sites, model results are estimates of pollutant concentrations. As such, the accuracy of these estimates is vulnerable to errors resulting from inadequate scientific formulation or inaccurate input and runtime parameters. As noted above, for application to industrial sources of certain air pollutants various models have been thoroughly investigated as to the accuracy for estimating resulting concentrations. However, less information is available for the application of models for estimating downwind concentrations of odor, hydrogen sulfide or ammonia from AFOs. This is complicated by the fact that the science of air quality issues associated with AFOs continues to evolve.

Of critical importance to the ability of any dispersion model to accurately estimate downwind concentrations of odor, hydrogen sulfide or ammonia is the availability of accurate and realistic estimates of pollutant emission rates from multiple types of sources. A single downwind pollutant concentration, whether measured or modeled, represents the sum of pollutant concentrations at that point which have been transported from multiple sources at differing locations. For an AFO this may include sources such as multiple exhaust fans and a lagoon, each of which may have different individual impacts at a downwind location. Many models are capable of simulating multiple types and numbers of pollutant emission sources simultaneously. However, the ability of the model to accurately estimate downwind pollutant concentrations remains highly dependent on an accurate estimate of pollutant emission rates from each source.

The Dispersion Modeling workgroup was formed to assess general issues such as those discussed above and provide answers for several specific questions. The following list of questions was provided as a starting point for the group's consideration:

1. What models are available that can accurately predict concentrations of pollutants downwind from a source?
2. What is the best model available that most accurately predicts concentrations of pollutants downwind from a source?
3. How difficult is the model to use?
4. What type of computer hardware and software is required to run the model?
5. How is the model obtained?
6. What are the inputs into the model and how easily are they obtained?
7. Are there any associated costs with purchasing or running the model (such as purchasing meteorological data)?
8. What physical mechanisms are represented within the model, what physical mechanisms are needed?
9. What atmospheric chemical processes affect odor, hydrogen sulfide and ammonia?
10. How far can odor, hydrogen sulfide and ammonia be expected to be transported?

Participants in the workgroup answered these questions and completed the group's charge of recommending a model or models that could be used to evaluate pollutant concentrations downwind from AFOs. It should be noted that while this group worked to identify a model proven for validity and accuracy specific to odor, hydrogen sulfide and ammonia from AFOs, the group concluded that the present scientific evidence is insufficient to identify such a model. Instead, the recommendation of this group identified the leading candidate for such air quality studies. Additional effort on comparing model predictions to observations is necessary. In the interim, the AERMOD dispersion modeling system can provide insight into not only the dispersion of odor, hydrogen sulfide and ammonia from AFOs, but possibly more important, insight into the relative efficacy of best management practices.

4.3 Methodology

The workgroup initiated efforts with a review of the goals for the group. In particular, participants identified the need to align the goals of the group with feasible deliverables. Development of new dispersion modeling systems and testing of existing systems for accuracy was considered beyond the scope of this effort. As a result, investigation by the group was directed toward identifying the best dispersion modeling system currently available which could estimate the relative change in pollutant concentrations resulting from changes in site management such as application of various best management practices. Focus was directed toward two primary areas; reviews of literature concerning dispersion modeling of odor, hydrogen sulfide and ammonia and model characteristics identified as critical to successfully simulating pollutant emissions from AFOs.

Four fields of generalized capabilities for candidate dispersion modeling systems were identified. These fields are:

- Emissions representation
- Physical atmospheric processes
- Chemical atmospheric processes
- Receptor / concentration (output) representation

4.3.1 Emissions Representation

AFOs contain multiple sources and types of sources of emissions of odor, hydrogen sulfide and ammonia. To be successful in estimating pollutant concentrations or the relative efficacy of best management practices, a dispersion modeling system must be able to represent the applicable types of sources. Examples of source types include indoors versus outdoors pits, above ground versus below ground, mechanical exhaust vents and naturally or curtain ventilated operations. Additionally, candidate models must have the ability to vary emission rates with time individually.

The emission source types existing at an AFO can be represented by several standard model representation schemes. Exhaust fans, for example, can be treated in a manner similar to how stacks at industrial sources are modeled. Lagoons and pits can be treated as area sources where the emissions are originating from a surface layer. In addition the height above ground of these release points or areas must be variable.

4.3.2 Physical Atmospheric Processes

Fundamentally, dispersion models represent how pollutants are transported by the wind from one point to another. During this transport, atmospheric mixing processes change the original pollutant concentration through dilution and/or deposition. As pollutants are transported further from their point of release this

dispersion continues to reduce the per unit concentration for the particular set of pollutants released from that point at a particular time. In addition, multiple releases from multiple locations may be mixed and transported in such a way as to converge at a downwind receptor point, and the per unit concentration a that point may not necessarily be less than that at the initial release points. These are examples of the physical processes that a candidate dispersion model must account for.

4.3.3 Chemical Atmospheric Processes

Changes in the downwind concentration of pollutants may be affected by atmospheric chemical process in addition to the physical process discussed above. For example, sulfur dioxide, a common pollutant emitted from combustion, undergoes various atmospheric chemical processes during its atmospheric lifetime. Over time, sulfur dioxide may react with ammonia to produce ammonia sulfate particulate matter. As part of the efforts of the workgroup, the need and availability of model formularizations that address atmospheric chemical processes for odor, hydrogen sulfide and ammonia were reviewed.

Complicating this review is the short spatial and temporal scales at which a candidate model for estimating downwind pollutant concentrations or relative efficacy of best management practices is expected to perform. The types of issues targeted for modeling analysis, such as estimated odor reduction from application of a specific best management practice, are generally local, or within approximately 3.1 miles (5 kilometers). At this distance, a light breeze of seven miles per hour will transport pollutants beyond five kilometers in approximately 30 minutes or more than a mile in ten minutes. As such, any chemical process must act on a time scale of minutes to be critical to the type of near-field concentration estimates that are the focus of this type of modeling effort.

Review of applicable literature identified pertinent discussion of treatment of chemical processes associated with emissions from AFOs. A study conducted by Earth Tech, Inc.,[4] confirms that for short spatial and temporal scales significant chemical transformation of pollutants from AFOs is negligible. As such, the need for mechanisms for treatment of atmospheric chemical processes was determined not to be critical at this time in the selection of a candidate modeling system. However, while the chemical formulation was not used as a determining factor in the final model selection, such model capabilities were reviewed throughout the process.

4.3.4 Receptor / Concentration (Output) Representation

Atmospheric dispersion models are designed to provide estimates of pollutant concentrations at a given location for a given time period. In regulatory applications the time periods in question are established in the National Ambient Air Quality Standards. For example, concentrations of sulfur dioxide considered harmful vary depending on the duration of exposure. These duration's are expressed as concentrations during a specific averaging period. For the example of sulfur dioxide, concentrations are evaluated on a 3-hour, 24-hour and annual basis. For odor, hydrogen sulfide and ammonia, various averaging periods could be applicable depending on the purpose of the application. For the purpose of this workgroup, model criteria concerning utility of model output was based on the ability of a model to be configured to assess multiple averaging periods.

Using these general criteria as a guide, the workgroup reviewed available models. A three phase approach was applied sequentially to eliminate candidate models from further consideration with the purpose of identifying one or more models that could be used to estimate downwind concentrations of

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[4] Earth Tech, Inc. Final Technical Work Paper for Air Quality and Odor Impacts. Prepared for the "Generic Environmental Impact Statement on Animal Agriculture." Earth Tech, Inc., Minneapolis, MN, March 2001.

odor, hydrogen sulfide and ammonia, and assess the relative efficacy of best management practices. Application and the resulting decisions are further discussed in the following sections of this document.

4.4 Candidate Models

The Environmental Protection Agency (EPA) Support Center for Regulatory Air Models (SCRAM) website[5] provided the initial list of candidate models. The website, operated and maintained by EPA, provides documentation and guidance on atmospheric dispersion models that support regulatory programs required by the Clean Air Act. Source codes and technical data, including information on basic design and purpose, are also provided for most models.

EPA classifies models as either preferred or recommended. Models deemed by EPA to be the most appropriate models available for regulatory applications are classified as "preferred", and are listed in Appendix A of the *Guideline on Air Quality Models (*published as Appendix W of 40 CFR Part 51)[6]. Refined air quality models for use on a case-by-case basis for individual regulatory applications are classified as "recommended". A justification for using a recommended model must be submitted prior to use for regulatory purposes. The list of candidate models contained the complete set of both preferred and recommended models.

In addition to those models found on the SCRAM website, several research-grade models were placed on the list of candidate models, including CAM[7], Farm Emissions Model & National Practices Model (FEM-NPM)[8] and STINK[9]. These proprietary models have typically been developed at colleges and universities to suit a specific need or purpose. Several models that are used in foreign countries to support regulatory programs were also added to the list, and these included Austrian Odour Dispersion Model (AODM)[10], Australian Plume Model (AUSPLUME)[11], and Fine Resolution Atmospheric Multi-Pollutant Exchange (FRAME)[12]. Although not recommended for use by EPA, these models have also undergone analysis and peer-review, and may have similar capabilities to air dispersion models used in the United States. Finally, the Integrated Puff (INPUFF-2)[13] and Computer-Aided Management of Emergency Operations/Arial Locations of Hazardous Atmospheres (CAMEO-ALOHA)[14] models were added to the list based on information provided in available literature. The model OFFSET[15], developed by the University of Minnesota, was not included on the list of candidate models because it is designed primarily as a tool used

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[5] http://www.epa.gov/ttn/scram/

[6] U.S. EPA. Revision to the Guideline on Air Quality Models: Adoption of a Preferred Long Range Transport Model and Other Revisions; Final Rule. 40 CFR Part 51, 2003.

[7] Bundy, D.S., and S. Hoff. Personal Communication. 2004

[8] Pinder, R. W., N. Anderson, R. Strader, C. Davidson, and P. Adams. Ammonia Emissions from Dairy Farms: Development of a Farm Model and Estimation of Emissions from the United States. 12th International Emission Inventory Conference "Emissions Inventories – Applying New Technologies," San Diego, CA, April 29 – May 1, 2003.

[9] Smith, R.J. and P.J. Watts. Determination of Odour Emission Rates from Cattle Feedlots: Part 2, Evaluation of Two Wind Tunnels of Different Size. Journal of Agricultural Engineering Research, 58: 231-240, 1994.

[10] Schaugerger, G., M. Piringer, and E. Petz. Diurnal and Annual Variation of the Sensation Distance of Odour Emitted by Livestock Buildings Calculated by the Austrian Odour Dispersion Model (AODM). Atmospheric Environment, 34: 4839-4851, 2000.

[11] EPAV (Victorian Environmental Protection Agency). AUSPLUME Gaussian Plume Dispersion Model User Manual. Environment Protection Authority, Government of Victoria, Melbourne, Australia, 2000.

[12] Dore, Anthony, et. Al. Modeling the Transport and Deposition of Sulphur and Reduced and Oxidised Nitrogen in the UK. Status Report to DEFRA, as a contribution to Long Range Transport of Pollutants in the UK. July, 2003. Available at: http://www.frame.ceh.ac.uk/reports.html.

[13] Petersen, W.B. and L.G. Lavdas. INPUFF 2.0 A Multiple Source Gaussian Puff Dispersion Algorithm – User's Guide. EPA/600/8-86-024. August, 1986.

[14] http://response.restoration.noaa.gov/cameo/cameo.html

[15] Jacobson, L., D. Schmidt, and S. Wood. OFFSET Odor From Feedlots Setback Estimation Tool. University of Minnesota Extension Service, 2002. Available at: http://www.extension.umn.edu/distribution/livestock systems/DI7680.html

to site new facilities for construction. OFFSET is not capable of predicting concentrations downwind of a facility.

The complete list of fifty-seven candidate models identified for consideration can be found in Table 4-1. The list was not intended to be an all-inclusive, comprehensive list of air dispersion models, but rather a list of those models supported by EPA or those where literature was readily available that indicated the model may be appropriate. After the list was finalized, a three phase approach was used to eliminate models from the list until only the most appropriate model(s) able to accurately predict the dispersion of ammonia, hydrogen sulfide, and/or odors from AFOs remained.

4.4.1 Phase 1

Thirty-three models were eliminated from consideration during Phase 1. During this phase, models whose cursory descriptions indicated that they would not be suitable or relevant for the purposes of the workgroup were removed. Only the basic capability of the model, or what the model could actually be expected to accomplish, was considered. For example, the Buoyant Line and Point Source Model (BLP)[16], a model designed to handle unique situations associated with aluminum reduction plants, and the Assessment System for Population Exposure Nationwide (ASPEN)[17] model, which is used to estimate toxic air pollutant concentrations over a large scale domains, were both removed. Models were also eliminated if the basic descriptions indicated that one model was superior over another. For example, some models are designed as "screening models" and are used to provide a rough, conservative estimate of concentrations prior to completing a more refined and accurate analysis. Therefore, a screening model was removed if a similar refined model was also on the list. Finally, models often improve over time, with some features of an older model being absorbed into newer, more accurate models. For this reason, only the most recent version of a model was considered during this process. A complete list of the models that were considered in Phase 2 is found in Table 4-1.

4.4.2 Phase 2

During Phase 2, the remaining twenty-four models were researched and reviewed to determine if they would be suitable for predicting concentrations of ammonia, hydrogen sulfide, and/or odors downwind of a source. Basic criteria, such as what the models require for full implementation in terms of license fees, training costs, hardware, data inputs and also purpose and capability, were used to evaluate the models. The resulting evaluations identified six remaining models that required more extensive research to determine their applicability towards AFOs. The list of remaining models included AERMOD, ADMS 3[18], AODM, CALPUFF[19], INPUFF-2, and STINK.

During phase 2, the Industrial Source Complex – Short-Term Model 3 (ISC-ST3) was removed from consideration. Although ISC-ST3 is currently EPA's preferred model for use in most regulatory analyses, the group found AERMOD to be superior in several key areas, such as advanced meteorological profiles, concentration distribution, and treatment of complex terrain, when compared directly to ISC-ST3.

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[16] Schulman, L. and J. Scire. Buoyant Line and Point Source (BLP) Dispersion Model User's Guide. Environmental Research & Technology, Inc., 1980.

[17] U.S. EPA. User's Guide for the Assessment System for Population Exposure Nationwide (ASPEN, Version 1.1) Model. EPA-454/R-00-017, April, 2000.

[18] Cambridge Environmental Research Consultants Ltd. (CERC). ADMS 2 User Guide Version 3.2. CERC, 3 Kings Parade, Cambridge, CB2 1SJ, UK. July, 2004.

[19] Earth Tech, Inc. CALPUFF Training Course Manual. Central States Air Resource Agencies Association (CenSARA), Kansas City, KS, November 17-19, 2003.

4.4.3 Phase 3

A detailed list of criteria was developed in Phase 3 of the evaluation to aid both in determining if the model has the capability to produce the desired output types, and also to compare the models amongst themselves. The list of criteria included:

1. Is the model user-friendly? Do you need to know a computer language? Does the model have a user interface, etc.?
2. What type of computer(s) is/are needed to run the model? Can the model run on a personal computer or does it need additional hardware, etc.?
3. Can in-house experience or skills be used to run the model? Will the model take extensive training to run?
4. What is the cost of the model? Is the software free or are there associated costs?
5. Does the model adequately characterize AFO emission source types? Does the model allow more than one source to be input? Does the model allow for different types of sources (point, area, line, pit, etc.)?
6. Does the model allow for wet and/or dry deposition?
7. Does the model adequately represent atmospheric chemical processes? Does the model provide specific processes for NH3, H2S, or odor, or does it treat all pollutants the same?
8. Are the format and/or type of model output usable for the evaluation of best management practices?
9. Is the model EPA approved? Preferred?
10. Does the model have both short and long term averaging periods?
11. Is the model designed for the appropriate size scale (1-5 km)?
12. What is the model's input data needs (meteorological data, terrain, etc.)?
13. Does the model account for building downwash?
14. Has the model been used previously for an AFO application? Is there any research that documents the use of the model for predicting NH3, H2S or odors from AFOs?

Each model was then extensively researched to determine to what extent it met the aforementioned criteria, to the extent possible.

4.4.3.1 AERMOD

The American Meteorological Society / Environmental Protection Agency Regulatory Model (AERMOD) exhibited the best collection of features of the six models that underwent extensive review. As such, the workgroup recommends application of AERMOD for estimation of odor, hydrogen sulfide and ammonia emissions from AFOs. Specific AERMOD features that make it suitable for this purpose include:

1) User-friendliness,
2) Able to run on a personal computer,
3) Does not take extensive training to operate,
4) Software available at no cost,
5) Able to characterize point, volume, area, area-polygon and area-circle source types,
6) Sophisticated in its handling of near-surface atmospheric mixing,
7) Could be used for the evaluation of best management practices,
8) Capable of handling both short and long term averaging periods,
9) Applicable to appropriate spatial scale,
10) Able to account for complex terrain (where downwind terrain is higher than the release height), and

11) Able to account for building downwash.

In addition to these features, Koppulu et. al.[20] compared AERMOD to STINK, and found the models comparable for the dispersion of odorous compounds.

One drawback to AERMOD is that the model is limited in its capability to treat atmospheric chemical processes, and odors are not explicitly part of the model. There are no specific processes included for treating ammonia or hydrogen sulfide. Only reactions involving sulfur dioxide are modeled using a simple chemistry scheme. However, AERMOD still compared well to the other models in this regard.

In addition, the current publicly available version of AERMOD does not have the ability to calculate wet and dry deposition. However, this functionality is currently being incorporated and beta testing is underway. It is anticipated that both wet and dry deposition will be included as a standard feature in future versions of AERMOD.

4.4.3.2 ADMS 3

The Atmospheric Dispersion Modeling System (ADMS 3) is maintained by Cambridge Environmental Research Consultants Ltd. (CERC) and contains several features that demonstrated potential usefulness for the purposes of the workgroup. ADMS 3 has the ability to handle both hourly sequential and statistical meteorological data, was classified as user friendly, provided for both wet and dry deposition, performed analyses on the appropriate scale, allowed for appropriate source types, and was able to account for complex terrain. However, the model also contained several inherent limitations, including:

1) Would require extensive training to operate,
2) Limitations on the number of area, line, and volume sources that could be used in the model for a single run (6 is the maximum), and
3) Potential cost concerns with both software (roughly $3,000) and training courses, which are only offered in the United Kingdom.

Despite the limitations, ADMS 3 does compare well with AERMOD in the treatment of dispersion and complex effects, and provides a variety of other options that are unavailable in AERMOD (short term fluctuations for odors, condensed plume visibility, puff release, and special treatment for coastline areas). However, the model did not compare well when considering the potential costs involved for both software and training.

4.4.3.3 AODM

The Austrian Odour Dispersion Model (AODM) uses standard Gaussian plume equations coupled with an emission module and a module to calculate instantaneous odor concentrations to evaluate downwind odor concentrations. The assessment of AODM indicated that the model would not be appropriate to use for the purposes of the workgroup, with respect to odor. In addition to being proprietary and therefore possibly unavailable to the public, AODM's drawbacks included:

1) The inability to predict concentrations from other than a single point source,
2) The inability to handle either wet or dry deposition,
3) A lack of reliability for distances less than 100 meters,

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[20] Koppulu, L., D.D. Schulte, S. Lin, M.J. Rinkol, D.P. Billesbach, and S.B. Verma. Comparison of AERMOD and STINK for Dispersion Modeling of Odorous Compounds. Paper No. 024015. ASAE Annual International Meeting, Chicago, Illinois, July, 2002.

4) The ability to handle only short, half-hour averaging periods,
6) An inability to deal with complex terrain or building downwash,
7) A lack of preferred or approved status with the EPA, and
8) A need for continuous fan exhaust rate data as a proxy for confinement temperatures.

While the model did demonstrate user-friendliness and minimal training requirements, AODM suffered from too many limitations to be used for the purposes of the workgroup.

4.4.3.4 CALPUFF

The non-steady state Lagrangian California Puff Model (CALPUFF) was recently elevated to EPA preferred model status based on its ability to simulate long-range phenomena such as visibility and acid deposition. In addition to backing by EPA, CALPUFF's strengths include:

1) Software is available at no cost,
2) Allows for both wet and dry deposition,
3) Contemplates appropriate source types and averaging periods, and
4) Handles building downwash and complex terrain.

Although CALPUFF can be used to predict downwind concentrations of ammonia, hydrogen sulfide and odors, the model is designed primarily for spatial scales beyond 5 kilometers, and therefore required more sophisticated meteorological data inputs than any of the other models reviewed. Previous applications of CALPUFF for AFOs focused on gauging the impact of a group of facilities over a county-wide area, rather than just a single facility on a local scale.[21]. In addition, Jacobson et. al.[22], states that CALPUFF is recommended for multi-facility applications, based on the technical advantages it provided for near-calm scenarios.

The goal of this workgroup was to identify a model or models that could accurately predict concentrations of ammonia, hydrogen sulfide or odors from a single facility. If future needs dictate a cumulative analysis over a geographic area containing multiple AFOs, CALPUFF may be a candidate model for such an exercise.

4.4.3.5 INPUFF -2

EPA developed the Integrated Puff (INPUFF-2) model to simulate the dispersion of buoyant or neutrally buoyant gas releases from both stationary and moving point sources. Although the effectiveness of INPUFF-2 in predicting odor concentrations downwind of a source or sources has been demonstrated[23], the model was found to be limited in several key aspects necessary for the accurate prediction of ammonia, hydrogen sulfide, or odors from an AFO. These limitations include:

1) Limited to point sources only, and unable to account for area or volume sources,
2) Unable to account for dry deposition,

[21] Pratt, G. Recommendations on the Combined Impact of Air Emissions from Multiple Feedlots – Draft. Minnesota Pollution Control Agency, November, 1999.
[22] Jacobson L.D., R. Moon, and J. Bicudo, et. Al. Generic Environmental Impact Statement on Animal Agriculture: Summary of the Literature Related to Air Quality and Odor. University of Minnesota, College of Agriculture, Food, and Environmental Sciences, 1999. Available at: http://www.mnplan.state.mn.us/pdf/1999/eqb/scoping/aircha.pdf
[23] Zhu, J., L. Jacobson, D. Schmidt, and R. Nicolai. Evaluation of INPUFF-2 Model for Predicting Downwind Odors from Animal Production Facilities. Applied Engineering in Agriculture, 16(2): 159-164, 2000.

3) Output is average of release durations, so unable to produce concentrations for various averaging periods,

4) Not recommended for modeling dense gas dispersions (such as hydrogen sulfide), and

5) Unable to account for complex terrain or building downwash.

As the limitations indicate, more flexibility is needed within the model to evaluate the full range of diverse animal facility types.

4.4.3.6 STINK

STINK is a research-grade, Gaussian plume model that was developed in Australia[24]. The workgroup was unable to obtain enough information on the specific features of STINK to make a practical decision on this model possible. Therefore, the model was dropped from consideration until more information becomes available or is brought to the attention of the workgroup.

4.5 Conclusion

AERMOD represents the state of the science in local scale dispersion modeling and therefore application of the AERMOD computer modeling system for atmospheric dispersion modeling of ammonia, hydrogen sulfide and odor from AFOs on a spatial scale of 5 kilometers or less is recommended at this time. Additional investigation into the absolute accuracy of modeled pollutant concentrations is also suggested.

Review of model applicability for estimating pollutant concentrations of ammonia, hydrogen sulfide and odor from AFOs yield many similarities to other, more common, dispersion modeling applications. These similarities include the release characteristics of pollutant emission sources at AFOs in addition to spatial and temporal scales commonly reviewed for industrial applications. Less correlation with common applications exist for unique pollutant specific characteristics and emission factor information.

In general, the field of dispersion modeling of ammonia, hydrogen sulfide and odor from AFOs is relatively new as compared to application of atmospheric dispersion models for federally mandated criteria pollutant emissions from industrial sources. It should be noted however, that the fundamental atmospheric processes of pollutant dispersion and transport are common to all sources and species of pollutant emissions regardless of the nature of the emitting process. This similarity allows future evaluation of absolute model performance for ammonia, hydrogen sulfide and odor to take advantage of the thirty plus years of advances in computational representation of atmospheric pollutant dispersion processes.

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[24] Smith, R.J. and P.J. Watts. Determination of Odour Emission Rates from Cattle Feedlots: Part 2, Evaluation of Two Wind Tunnels of Different Size. Journal of Agricultural Engineering Research, 58:231-240, 1994.

Table 4-1

List of Candidate Models

Model	Eliminated in Phase 1	Eliminated in Phase 2	Eliminated in Phase 3	Recommended Model
ADAM		X		
ADMS 3			X	
AERMOD				X
AFTOX	X			
AODM			X	
ASPEN/EMS-HAP	X			
AUSPLUME		X		
AVACTA II		X		
BLP	X			
CALINE 3	X			
CALPUFF			X	
CAL3QHC/CALQHCR	X			
CAM		X		
CAMEO/ALOHA		X		
CAMx	X			
CDM2	X			
CMAQ	X			
COMPLEX 1	X			
CTDMPLUS		X		
CTSCREEN	X			
DEGADIS		X		
EKMA	X			
ERT	X			
FEM-NPM		X		
FRAME		X		
HGSYSTEM	X			
HOTMAC	X			
INPUFF 2			X	
ISCST3		X		
LONG Z	X			
MESOPUFF II	X			
MTDDIS	X			
OB ODM	X			
OCD	X			
OZIPRZ	X			
PAL		X		
Panache		X		
PLUVUE II	X			
PPSP	X			
RAPTAD		X		
RAM		X		
RPM IV		X		

Model	Eliminated in Phase 1	Eliminated in Phase 2	Eliminated in Phase 3	Recommended Model
RTDM 3.2		X		
SCIPUFF	X			
SCREEN 3	X			
SCSTER	X			
SDM	X			
SHORT Z		X		
Simple Line Source	X			
SLAB		X		
STINK			X	
TSCREEN	X			
UAM IV	X			
UAM V	X			
VALLEY	X			
VISCREEN	X			
WYNDVALLEY	X			